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EFFICIENT CROSS-LAYER DESIGN ARCHITECTURE FOR ROUTING AND CHANNEL SELECTION IN MULTI-RADIO MULTI-CHANNEL WIRELESS MESH NETWORKS

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ABSTRACT

In wireless mesh network, there is a need of efficient Cross-Layer Design Architecture for Routing and Channel Selection in Multi-Radio Multi-Channel Wireless Mesh Networks. For this we propose interference and congestion aware cross-layer architecture for wireless mesh networks. The proposed technique first we apply Cross-Layer QoS-Aware Routing Protocol, in which we use bandwidth estimation for physical routing and ICA metric for logical routing. We select the channel by using Channel Quality Variables at last we Optimize and adjust the cross-layer metrics using delay dissatisfaction ratio, Throughput dissatisfaction ratio and PER dissatisfaction ratio. Our proposed technique selects high quality paths and interference free channels also makes effective utilization of the available interfaces and prioritizes the packets in the event of congestion.

Keywords: *Architecture, Routing, Channel Selection, Mesh Networks, QoS*

1. INTRODUCTION

1.1 Wireless Mesh Networks (WMN)

WMN is comprised of a combination of static mesh routers and mobile mesh nodes (MNs). Mesh routers form a wireless backbone infrastructure. Some mesh routers function as the gateways and are connected via wired links to the Internet. MNs access the network via a mesh router which serves as the access point (AP). WMNs may cover a large area with low deployment cost. It is usually connected to the Internet to provide users with backhaul access. WMNs integrate both ad hoc and infrastructure operation modes and interwork with other wireless networks. Furthermore, it is more concerned with scalable end-to-end throughput and satisfactory quality of service (QoS) to deliver heterogeneous traffic. An important consideration in the design of a mesh network is the network's ability to efficiently support high-throughput multicast applications (e.g., video streaming broadcast) over wireless links [1] [2] [3].

1.2 Cross-Layer Design Architecture for Wireless Mesh Networks

Multi-hop wireless networks requires new challenges such as varying the nature of the signal strength, higher bit-error rates, dynamic variations in channel quality, fading effects, interference problems, mobility, shared and contention based MAC, multi-hop transmission and path selection at network layer. All these need some degree of interaction amongst different layers so that to optimize the overall network performance. In order to solve such problems, cross layer information exchange is used. The basic purpose of cross layer design use multilayer parameters from OSI stack to increase the efficiency and performance of multi-hop wireless networks. Cross layer design approach can be used to improve the overall performance of multi-hop wireless networks such as wireless sensor networks (WSN), mobile ad hoc networks (MANET), and wireless mesh networks (WMN) [4].

1.3 Issues of Cross-Layer Design Architecture for Wireless Mesh Networks

There are some issues of cross-layer design architecture for wireless mesh networks. Like, it has some risks due to loss of protocol-layer abstraction, incompatibility with existing protocols, and unforeseen impact on the future design of the network and difficulty in maintenance and management [2].

1.4 Problem Identification

We analysed some papers related to cross-layer design architecture for wireless mesh networks under literature review section and indentify some problems in these works like in paper [8], a Cross-Layer QoS-aware routing protocol based on OLSR (CLQ-OLSR) have been proposed for supporting real-time multimedia communication by efficiently exploiting multi-radio and multi-channel method. By creating multi-layer virtual logical mapping over physical topology, they have designed two sets of routing mechanisms: physical modified OLSR protocol (MOLSR) and logical routing, to accommodate network traffic. By piggybacking bandwidth information in HELLO and Topology Control (TC) messages, each node spreads topology and bandwidth information in the whole network. But this work fails to address the interference and congestion which are the main issues of WMN.

Some authors have worked on this like Byung Joon Oh and Chang Wen Chen [5] projected a new cross-layer framework for MAC protocol for a QoS-guaranteed delivery of the H.264 video streaming over wireless mesh networks. Chi Harold Li *et al.* [6] presented a fresh cross layer framework of QoS routing and distributed opportunistic scheduling for wireless mesh network which provides resource reservation for QoS flows. Xiang-lin Zhu [7] have proposed a novel routing algorithm named TDTPA which is based on the WMNs access scheme design to advance the networks presentation. Yuhuai Peng *et al.* [8] have proposed OLSR (CLQ-OLSR) to support real-time multimedia communication by professionally developing multi-radio and multi-channel method and Narayan D G et al. [9] have deliberate a fresh cross layer routing metric called Interference and Congestion Aware (ICA) metric by considering Re-transmission count (RTC) from MAC layer. The works of these authors are discussed in detail under literature review section.

2. LITERATURE REVIEW

Byung Joon Oh and Chang Wen Chen [5] have proposed a novel cross-layer framework for MAC protocol for a QoS-guaranteed delivery of the H.264 video streaming over wireless mesh networks. Based on the unique feature of wireless mesh networks, they have developed a Cross-Layer Adaptation HCCA MAC making full use of the Link Capacity Estimation information for the adaptation as well as the application of Video-Adaptive FEC to combat wireless channel impairments. They have also adopted both network-level QoS metrics (bit rate, drop rate and packets delay) as well as received video quality at the receiving node to evaluate the proposed CLA-HCCA MAC scheme against the PRBACHCCA MAC scheme for H.264 video over WMNs. Results shows that this scheme is able to substantially outperform the state-of-the-art scheme PRBAC-HCCA MAC with an average of 5.5dB in reconstructed video quality. However it is not scalable and cannot support robust time-bounded media applications.

Chi Harold Li *et al.* [6] have proposed a novel cross layer framework of QoS routing and distributed opportunistic scheduling for wireless mesh network which provides resource reservation for QoS flows. Studies with different scheduling algorithms and routing protocols have shown that their algorithm successfully guarantees various QoS requirements and achieves higher network throughput when compared with other standard techniques. The main advantage is that this frame work achieves higher network performance gain and better QoS guarantees in comparison to other benchmark protocols. However there is an overall delay in the performance.

Xiang-lin Zhu [7] have proposed a novel routing algorithm based on the WMNs access scheme design to improve the networks performance. The new scheme, which is called TDTPA, guarantees the QoS for different data streams through cross-layer design to accomplish the token distribution and target programming without bringing heavy extra-load. Both theoretical analyses and simulation results show that the proposed algorithm outperforms the existing protocols for WMNs in terms of the packet success delivery ratio (PSDR), average point-to-point delay (APPD) and routing consumption. However the whole target programming minimizes the probes transmission range while they are forwarded.

Yuhuai Peng *et al.* [8] have proposed a Cross-Layer QoS-aware routing protocol based on OLSR (CLQ-OLSR) to support real-time multimedia communication by efficiently exploiting multi-radio and multi-channel method. By constructing multi-layer virtual logical mapping over physical topology, they have designed two sets of routing mechanisms: physical modified OLSR protocol (MOLSR) and logical routing, to accommodate network traffic. By piggybacking bandwidth information in HELLO and Topology Control (TC) messages, each node disseminates topology and bandwidth information in the whole network.

Simulation experiments on QualNet demonstrate that the proposed CLQOLSR outperforms single radio OLSR (SR-OLSR), multi-radio OLSR (MR-OLSR) and OLSR with Differentiated Services (DiffServ) in terms of network aggregate throughput, end-to-end packet delivery ratio, end-to-end delay and end-to end delay jitter with reasonable message overheads and hardware costs. In particular, the network aggregate throughput for CLQ-OLSR can almost improve by 300% compared with the single radio case. However there is overhead in the performance.

Narayan D G *et al.* [9] have proposed a joint problem of routing and interface assignment for Multi-Radio Wireless Mesh Networks (WMNs) to improve the performance of the network. They have designed a novel cross layer routing metric called Interference and Congestion Aware (ICA) metric by considering Re-transmission count (RTC) from MAC layer, congestion at different interfaces of each node and intra-flow interference to find the optimal path. Later, they have also extended the work by prioritizing the network traffic by assigning different interfaces to different traffics like video, audio and data by considering the load on each interface and thus providing good QoS. The results reveal that this joint approach performs better in terms of throughput, average end-to-end delay and packet delivery fraction than existing routing metric WCETT. However video packets have more throughputs compared to audio and data packets which are least. This is because video packets are queued in lightly loaded interface, audio packets in medium loaded interface and data packets in highly loaded interface.

3 PROPOSED SOLUTION

3.1 Overview

In this paper, we design interference and congestion aware cross-layer architecture for wireless mesh networks. For this purpose, we use the estimated available bandwidth metric for physical path establishment under CLQ-OLSR [8], while for logical path establishment we use ICA metric [9].

At first phase we use Cross-Layer QoS-aware routing protocol based on OLSR (CLQ-OLSR) [8]. CLQ-OLSR have two parts first is physical routing and second is logical routing. Physical routing customized OLSR protocol through bandwidth estimation function (M-OLSR) and logical routing is another autonomous pathway establishment apparatus based on topology and bandwidth information. For physical path establishment we use estimated available bandwidth metric while for logical path establishment we use ICA metric [9].

At second phase we select channel. It is distributed channel selection phase, for selection of channel we use Channel Quality Variables (CQV). It represents the inverse measure to the quality observed by a node at a specific channel. In order to reduce the interference cause by control traffic, among the multiple interfaces, the control interface is exclusively use for control traffic. But if all non-control wireless interfaces become congested, the control interface is shared for data traffic.

At final phase, once the data is routed through the selected optimal path, we collect the delay dissatisfaction ratio, Throughput dissatisfaction ratio and PER dissatisfaction ratio [6] as feedback from the destination and optimized the route selection process by suitably adjusting the cross-layer metrics.

This allows a routing algorithm to select high quality paths and interference free channels as well as eliminate the overhead associated with active monitoring techniques. Also, it makes effective utilization of the available interfaces and prioritizes the packets in the event of congestion. The block diagram of the proposed solution is given in Fig.1.

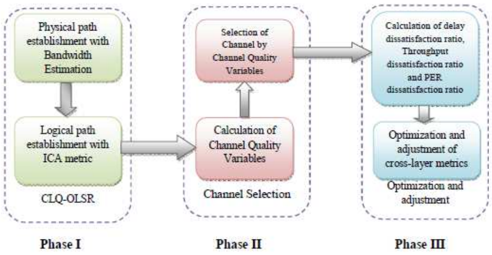

Fig 1: Block Diagram of Proposed Solution

3.2 Estimation of Metrics

3.2.1 Interference and Congestion Aware (ICA) Routing Metric

Interference and Congestion aware routing metric works on passive monitoring mechanism by reducing the control overhead in the network and it is isotonic. There are basically two parts of ICA metric. In which one is related to Load and the other detains the Intra-flow Interference.

Mathematically, Interference and Congestion aware routing metric for path m is described as follows [9]

$$Metric_{(ICA)}(m) = \sum_{link\, i \in m}^{x} L_i + \sum_{link\, i \in m}^{x} IF_i \quad (1)$$

Where,

x = number of link of path m,

L_i = load on every interface,

IF_i = intra-flow interference channel diversity.

Furthermore, these parameters are discuss in detail in next section

3.2.1.1 Calculation of Interface Load

In Interference and Congestion aware routing metric, the LOAD constituent incarcerates the congestion at every interface of a node by taking into account the queue length and RTC.

The L_i for each interface i, is distinct as

$$L_i = \frac{QL_{Avg}}{QL_{Max}} + \frac{nRT_{Avg}}{nRT_{Max}} \quad (2)$$

Where,

QL_{Avg} = Average queue length,

QL_{Max} = Maximum queue length,

nRT_{Avg} = Average Re-transmission count,

nRT_{Max} = Maximum Re-transmission count.

3.2.1.2 Calculation of Average Queue Length

The average queue length can be calculated by the following equation.

$$QL_{Avg} = \alpha * QL_i + (1 - \alpha) * QL_{Avg} \quad (3)$$

Where,

QL_{Avg} = Average queue length,

QL_i = Current queue length.

3.2.1.3 Calculation of Average value of Re-transmission Cost

The Average Re-transmission count can be calculated by the equation given below.

$$nRT_{Avg} = \alpha * nRT_i + (1 - \alpha) * nRT_{Avg} \quad (4)$$

Where,

nRT_{Avg} = Average value of Re-transmission count,

nRT_i = Instant value of Re-transmission count.

3.2.1.4 Calculation of intra-flow interference channel diversity

For the calculation of intra-flow interference channel diversity, we consider a situation in which the source has two paths to the sink and have same weights considering congestion and re-transmission count, so the path have less intra-flow interference if it use different channels to transmit the data in comparison of the path that use same channel to transmit the data.

The intra-flow interference channel diversity IF_i for link 'i' can be calculated by the following formula.

$$IF_i = \begin{cases} p1 \rightarrow X_{i-1} \neq X_i \\ p2 \rightarrow X_{i-1} = X_i \end{cases} \quad (5)$$

And $0 \leq p1 \leq p2$

Where,

X_i = channel use by node i,

X_{i-1} = channel use by node i-1,

p1, p2 = weight of the paths.

3.2.2 Bandwidth Estimation

For bandwidth estimation we use passive listening method. This method computes the idle periods of the shared wireless media. In this method every node listens to the channel to conclude the channel status and calculates the idle interval for a period of time T.

Each node regularly observes the channel state changes. It starts counting when the channel state switches from busy status to idle state and stops counting when channel state goes from idle state to busy state. The idle time is collection of numerous idle times during an inspection interval T.

The idle time is divided by the observation interval T to estimate the idle ratio and multiply it with the raw channel bandwidth (2Mbps for standard IEEE 802.11) to attain the obtainable bandwidth [8].

Mathematically, the available bandwidth for each channel for a period of time T can be calculated by the formula given below [8],

$$BW_k(m) = IR_{n\_idle}(m) \times M_{n\_\max}(m), \quad (6)$$

and $$IR_{idle} = \frac{T_{idle}}{T}, \quad (7)$$

The channel with the largest $BW(m)$ value in the channel usage lists is selected greedily, when the channel assignment is done among K-1 real-time radios in transmitting a packet. The selection of channel 'm' in channel assignment is depends on the value of $BW(m)$.

The probability of choosing channel m as is as follow

$$P_m = BW_k(m) \Big/ \sum_{m=1}^{k-1} BW_k(m) \quad (8)$$

If we assume that the available bandwidth of various channels could be added then we can take the sum of weight of available bandwidth as the available bandwidth of node k.

Hence, the total available bandwidth BW_k for real-time traffic over node k is calculated by the equation given below,

$$BW_k = \sum_{m=1}^{K-1} P_m \times BW_k(m) \quad (9)$$

3.2.3 Channel Quality Variables (CQVs)

A CQV acts as an inverse measure to the quality experiential by a node at a definite channel it is a dimensionless variable. The lower value of CQV for a channel denotes better to start a new conversation using that channel. For tuning the node for every orthogonal channel, every node holds a vector of CQV values.

Channel Quality Variables for channel 'm' and node 'i' is denoted as CV_m^i and Channel Quality Variables can be calculated by the formula given below [10].

$$CV_m = \left[CV_m^a, CV_m^b, CV_m^c \right] \quad (10)$$

Where,

CV_m^a = Vector of CQV for channel 'm' and node 'a',

CV_m^b = Vector of CQV for channel 'm' and node 'b' and

CV_m^c = Vector of CQV for channel 'm' and node 'c'

Channels that are snobbish for the transport of data packets are started with CV = 0. The default channel gets a startup consequence and it is initialized with a non-zero CV.

3.2.4 Delay Dissatisfaction Ratio

The Delay Dissatisfaction Ratio for route β_{st}^k is distinct as the real delay dimension, $\sum_{(a,b)\in\beta_{st}^k} Dly_{ab}^x$ over quality of service delay requirement Dly_{req} [6]

Mathematically,

$$DDR(m) = \frac{\sum_{(a,b)\in\beta_{st}^k} Dly_{ab}^x}{(1-\alpha_{Dly})\, Dly_{req}} \quad (11)$$

Where,

$$\beta_{st}^k = \{(x_a, x_b) \mid \forall\, x_a, x_b \in X_R \cup X_G, k = 1, 2, \ldots\ldots, n\} \quad (12)$$

And, x_a, x_b are set of links,

$$X_R = \{x_r \mid r = 1, 2, \ldots\ldots\ldots\ldots, n_r\}$$
$$X_G = \{x_g \mid r = 1, 2, \ldots\ldots\ldots\ldots, n_g\}$$

3.2.5 Throughput Dissatisfaction Ratio

Throughput dissatisfaction ratio is defined as the ratio between the throughput requirement TP_{req} and actual bottleneck link throughput, $\min_{(a,b)\in\beta_{st}^k} T_{ab}^x$ is minimum of all one hop throughput beside the route β_{st}^k [6].

Mathematically,

$$TP(m) = \frac{(1+\alpha_{TP})T_{req}}{\min_{(a,b)\in\beta_{st}^k} T_{ab}^x} \quad (13)$$

3.2.6 PER Dissatisfaction Ratio

PER dissatisfaction ratio is distinct as the multiplication of entire one-hop error rate, $1-\prod_{(a,b)\in\beta_{st}^k}(1-E_{ab}^x)$ to PER requirement E_{req} [6]

$$PerDR(m) = \frac{1-\prod_{(a,b)\in\beta_{st}^k}(1-E_{ab}^x)}{(1-\alpha_E)E_{req}} \quad (14)$$

In the above equation (10) (12) (13), $\alpha_{Dly}, \alpha_{TP}, and\ \alpha_E$ represents resource reservation margin factor.

Phase I

3.3 Cross-Layer QoS-Aware Routing Protocol Based on OLSR with ICA

At first phase we will apply Cross-Layer QoS-Aware Routing Protocol which is based on OLSR (CLQ-OLSR) for routing purpose. CLQ-OLSR has two parts which are physical routing and logical routing as shown by Fig.2.

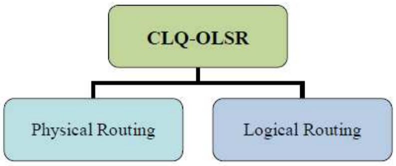

Fig 2: CLQ-OLSR

Physical routing modified OLSR protocol by the mean of bandwidth estimation function and logical routing is another autonomous pathway establishment apparatus, which is based on bandwidth information and topology. The protocol stack of CLQ-OLSR is presented in Fig.3.

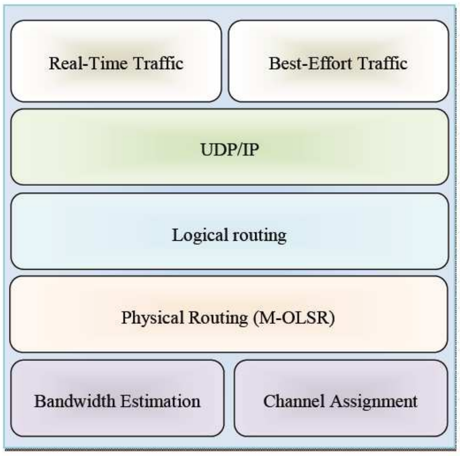

Fig 3: Protocol Stack Of CLQ-OLSR

3.3.1 Physical Routing System

3.3.1.1 Physical Routing

In physical routing we will discuss working mechanism and bandwidth estimation. The physical routing become heir to the stability of the link state algorithm and also makes the routes instantly accessible by its proactive character. Further, it reduces flooding of control messages by using only the preferred nodes. That is called multipoint relays (MPRs) which are applied to distribute them all over the network. In the intervening time, it pronounces the state of barely a compartment of links that are connected with the neighbors that are its multipoint relay selectors.

Each node set a group of some nodes as MPRs from its one hop neighbors to forward the control message in flooding. MPRs are selected to delivers the control messages to all nodes two hops away. Each node sends control messages regularly, that messages content sequence number of most current information to accomplish in-order delivery. There are three types of control messages in M-OLSR, which are HELLO, TC and Multiple Interface Declaration (MID). HELLO messages are use for link sensing, neighbor detection and MPR signaling. TC messages holds advertisement of link state or topology declaration. MID messages declares the presence of manifold interfaces on single node. In physical routing path calculation is done by shortest path algorithm as depicted by Fig.4. This algorithm is commences every time when there is a link status change, network topology, neighbors or multiple interfaces.

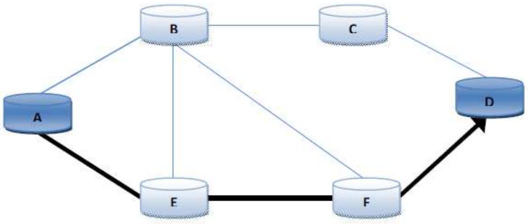

Fig 4: Physical Routing

For physical path establishment we use estimated available bandwidth which will be calculated below

3.3.1.2 Bandwidth Estimation

For the estimation of available bandwidth we will apply passive listening method. Passive listening method of bandwidth estimation computes the idle phase of the communal wireless media. All nodes eavesdrop to the channel to decide the channel condition and calculate the idle interval for a period of time T. Each node regularly scrutinizes the channel state changes and starts counting when the channel state changes from busy status to idle state and stops counting when channel state goes from idle state to busy state.

Step 1

In the bandwidth estimation process first we calculate the idle ratio by using the equation (7) in which we divide the idle time by the observation interval T.

Step 2

After the calculation of ideal ratio we calculate the available bandwidth ($BW(m)$) for each channel for a period of time T by using equation (6)

Step 3

The channel with the largest $BW(m)$ value in the channel usage lists is selected greedily, when the channel assignment is done among K-1 real-time radios in transmitting a packet. The selection of channel 'm' in channel assignment is depends on the value of $BW(m)$.

Step 4

Since, the selection of channel 'm' in channel assignment is depends on the value of $BW(m)$. So we calculate the probability of choosing channel m (P_m) by using equation (8).

Step 5

Finally, we calculate the total available bandwidth BW_k for real-time traffic over node k by using the equation (9), in which we use available bandwidth for each channel $BW(m)$ and probability of choosing channel m P_m. Those are calculated in step 2 and step 4.

Now this estimate bandwidth can be use for physical routing.

3.3.2 Logical Routing System

3.3.2.1 Logical Routing

The logical routing is established for balancing the network load and evading traverse a physical path containing any crammed links, accepting the real-time traffic through demanding QoS requisite. The logical routing (Fig 5) can be done by applying following steps.

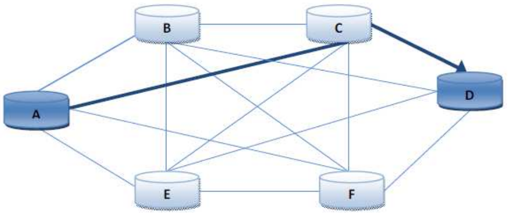

Fig 5: Logical Routing

Step 1

When a packet to the new sink is generated then a source node creates a logical routing to that sink for the session.

Step 2

The source node generates a full mesh topology by using the information from physical network topology and estimated bandwidth. Each logical link in logical routing is correspondence to the physical path between sources to sink in physical routing.

Step 3

An optimized route regarding bandwidth value and hop count to sink node is selected by source node

Step 4

Finally, the logical path with the largest available bandwidth in the set is chosen for the session.

Here for the selection of logical path we use interference and congestion aware (ICA) routing metric which is calculated below.

3.3.2.2 Calculation of Interference and Congestion Aware (ICA) Routing Metric

Interference and Congestion aware (ICA) routing metric is isotonic that works on passive monitoring mechanism by reducing the control overhead in the network. There are basically two part of ICA metrics in which first one is related to Load and the other detains the Intra-flow Interference.

The ICA metrics can be calculated by using equation (1)

Since ICA metric is combination of load on every interface (L_i) and intra-flow interference channel diversity (IF_i). So for calculation n of ICA metric we have to calculate first load on every interface (L_i) and intra-flow interference channel diversity (IF_i)

Step 1

At first, we calculate Interface Load (L_i) for each interface i by using equation (2), for calculation of (L_i) we consider average and maximum queue length with average and maximum re-transmission count as describe in equation (2). The average queue length and average re-transmission count is calculated by using equations (3) and (4) respectively.

Step 2

After calculation of Interface Load (L_i), For the calculation of intra-flow interference channel diversity, we assume a situation in which the source has two paths to the destination and have same weights taking into account congestion and re-transmission count and we calculate intra-flow interference channel diversity (IF_i) for link ‘i’ by using equation (5).

Step 3

After calculating Interface Load (L_i) and intra-flow interference channel diversity (IF_i) we use their values in equation (1) and calculate ICA metric.

This ICA metric is use in logical routing for selecting the path.

Phase II

3.4 Selection of Channel

After the routing processes we select channel. For selection of channel we use we use Channel Quality Variables (CV) [10].It is distributed channel selection phase, for selection of channel. Lower the value of Channel Quality Variables of the channel will be better of the selection of that channel to start conversation. So the channel with the lowest value of Channel Quality Variables will be best for selection. Therefore, we select the channels that have lowest value of Channel Quality Variables.

Step 1

At the first step, we calculate the Channel Quality Variables (CV) for each channel that have to be selected. For calculation of Channel Quality Variables (CV) we use equation (10).

Step 2

After the calculation of Channel Quality Variables (CV) for all channels, we enlist them into a table as describe below. Then re-arrange the table according to Channel Quality Variables (CV). The lowest value of Channel Quality Variables (CV) will be at rank 1

Table 1

Rank	**Channel**	**Channel Quality Variables (CV)**
1	m(2)	$CV_{m(2)} = 0.21$
2	m(1)	$CV_{m(1)} = 0.53$
. . .		
n	m(n)	$CV_{m(n)} = 1.3$

In table 1 the channel m (2) has the least value of Channel Quality Variables (CV) so it is at the rank 1.

Step 3

After re-arrangement of table we select the channel which is at rank 1 for communication. Since the channel which is at rank 1 have the least value of Channel Quality Variables (CV) and the least value of Channel Quality Variables (CV) is best for selection of that channel for communication, so we select the channel which is at rank 1.

Phase III

At final phase, once the data is routed through the selected optimal path we calculate some performance metrics to optimizing our propose method.

We calculate The Delay Dissatisfaction Ratio for route by using equation (11), Throughput dissatisfaction ratio by using equation (13) and PER dissatisfaction ratio by using equation (14) as feedback from the destination and optimized the route selection process by suitably adjusting the cross-layer metrics. The Flow chart given in Fig.6 gives the entire steps involved in the solution.

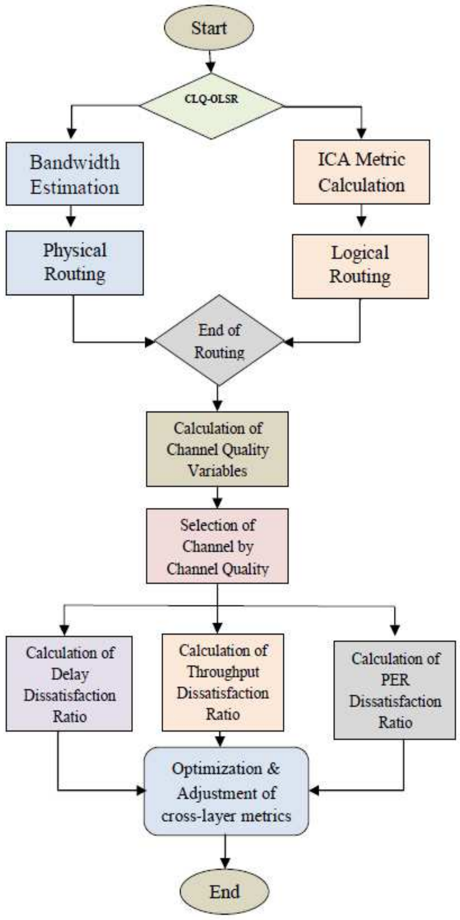

Fig 6: Flow chart of proposed solution.

4. SIMULATION RESULTS

4.1 Simulation Model and Parameters

The Network Simulator (NS2) [11], is used to simulate the proposed architecture. In the simulation, 110 mobile nodes move in a 1250 meter x 1250 meter region for 25 seconds of simulation time. All nodes have the same transmission range of 250 meters. The simulated traffic is Constant Bit Rate (CBR).

The simulation settings and parameters are summarized in table.

No. of Nodes	110
Area Size	1250 X 1250
Mac	IEEE 802.11
Transmission Range	250m
Simulation Time	25 sec
Traffic Source	CBR
Packet Size	512
Sources	10
Rate	50,100,150,200 and 250kb
Flows	2,4,6,8 and 10

4.2 Performance Metrics

The proposed Efficient Cross-Layer Design Architecture for Routing and Channel Selection (ECDA) is compared with the CLQ-OLSR technique [8]. The performance is evaluated mainly, according to the following metrics.

- **Packet Delivery Ratio:** It is the ratio between the number of packets received and the number of packets sent.
- **Throughput**: It refers the average number of packets received by the receiver during the transmission
- **Delay**: It is the amount of time taken by the nodes to transmit the data packets.
- **Received Bandwidth**: It is the number of bits received by the receiver.

4.3 Results

1) Based on Flows

In our first experiment we vary the number of flows as 2,4,6,8 and 10.

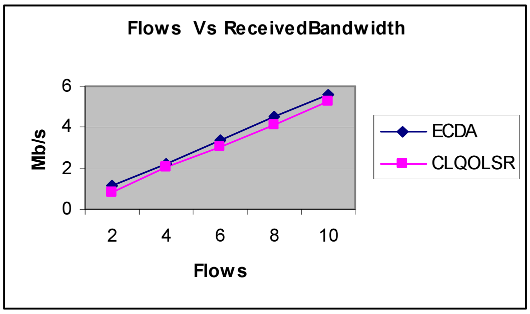

Fig 7: Flows Vs Received Bandwidth

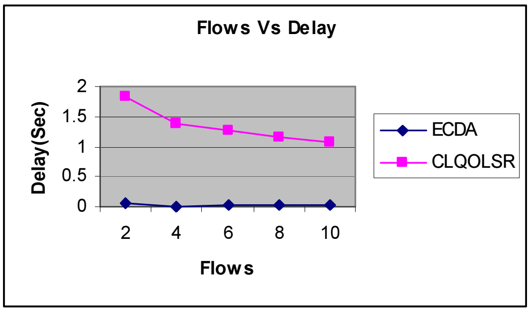

Fig 8: Flows Vs Delay

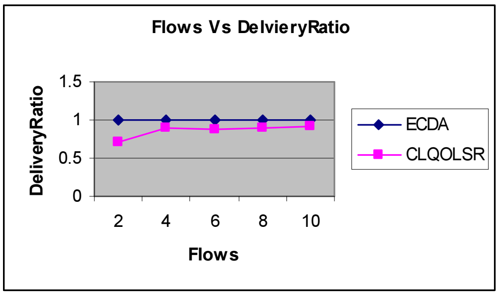

Fig 9: Flows Vs Delivery Ratio

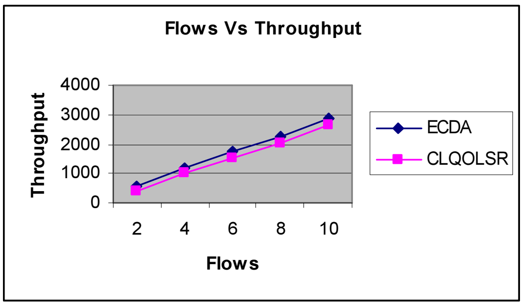

Fig 10: Flows Vs Throughput

Figure 7 shows the received bandwidth of ECDA and CLQ-OLSR techniques for different number of flows scenario. We can conclude that the received bandwidth of our proposed ECDA approach has 13% of higher than CLQ-OLSR approach.

Figure 8 shows the delay of ECDA and CLQ-OLSR techniques for different number of flows scenario. We can conclude that the received bandwidth of our proposed ECDA approach has 98% of less than CLQ-OLSR approach.

Figure 9 shows the delivery ratio of ECDA and CLQ-OLSR techniques for different number of flows scenario. We can conclude that the delivery ratio of our proposed ECDA approach has 14% of higher than CLQ-OLSR approach.

Figure 10 shows the throughput of ECDA and CLQ-OLSR techniques for different number of flows scenario. We can conclude that the throughput of our proposed ECDA approach has 14% of higher than CLQ-OLSR approach.

2) Based on Rate

In our second experiment we vary the transmission rate as 50,100,150,200 and 250Kb.

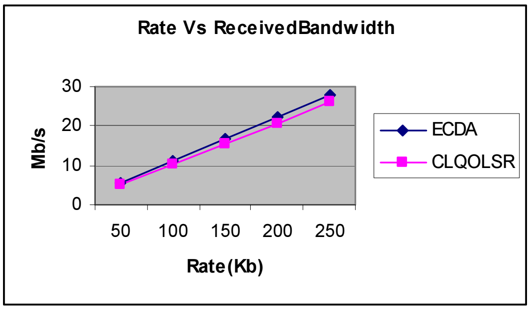

Fig 11: Rate Vs Received Bandwidth

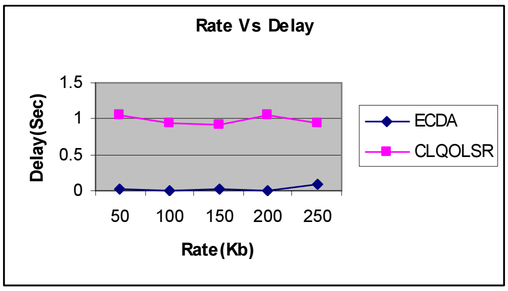

Fig 12: Rate Vs Delay

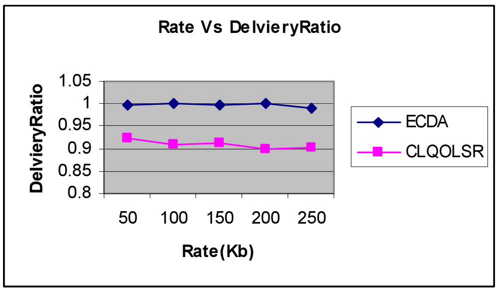

Fig 13: Rate Vs Delivery Ratio

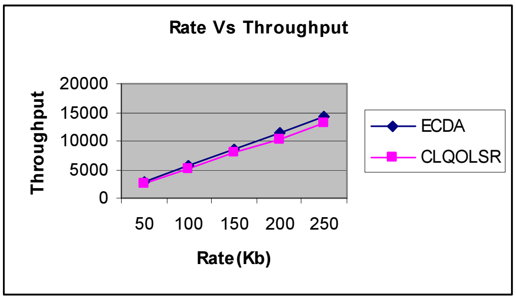

Fig 14: Rate Vs Throughput

Figure 11 shows the received bandwidth of ECDA and CLQ-OLSR techniques for different rate scenario. We can conclude that the received bandwidth of our proposed ECDA approach has 7% of higher than CLQ-OLSR approach.

Figure 12 shows the delay of ECDA and CLQ-OLSR techniques for different rate scenario. We can conclude that the received bandwidth of our proposed ECDA approach has 97% of less than CLQ-OLSR approach.

Figure 13 shows the delivery ratio of ECDA and CLQ-OLSR techniques for different rate scenario. We can conclude that the delivery ratio of our proposed ECDA approach has 9% of higher than CLQ-OLSR approach.

Figure 14 shows the throughput of ECDA and CLQ-OLSR techniques for different rate scenario. We can conclude that the throughput of our proposed ECDA approach has 9% of higher than CLQ-OLSR approach.

5 CONCLUSIONS

In this paper, we proposed interference and congestion aware cross-layer architecture for wireless mesh networks. In this proposed technique, we use bandwidth estimation and ICA metric for physical routing and logical routing and set Cross-Layer QoS-Aware Routing Protocol based on OLSR. We applied Channel Quality Variables to select the best channel. For the optimization and adjustment of cross-layer metrics we used delay dissatisfaction ratio, throughput dissatisfaction ratio and PER dissatisfaction ratio. Our proposed interference and congestion aware cross-layer architecture is able to select high quality paths and interference free channels and also eradicate the overhead related with active monitoring techniques.

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